3.3.3. Dynamic Non-maneuvering Position Accuracy

3.3.3.1. Purpose

The purpose of this test is to measure the dynamic, non-maneuvering position accuracy of the INS, to isolate the effects of non-maneuvering flight upon the INS, to isolate any degradation in accuracy due to an airborne vice ground alignment, and to qualitatively assess the utility of the INS as a navigation aid in the non-maneuvering environment.

3.3.3.2. General

Static testing provided a baseline of accuracy over time caused by errors inherent to the INS platform, accelerometers and gyroscopes. Dynamic, non-maneuvering position accuracy testing provides the next logical step in fully testing the INS. While airborne, the aircraft is flown in navigation profiles designed to demonstrate the effects of aircraft movement during flight while minimizing any maneuvering. The profiles are flown over maximum north-south and east-west distances to excite the effects of earth rate and coriolis. The flight duration should be equal to the maximum mission duration or two Schuler cycles, whichever is shorter. The optimum technique is to perform one flight on a predominately east-west profile and one on a predominately north-south profile. The maximum cruise range speeds should be used to allow the maximum latitude and longitude to be covered.

The flyover method explained earlier is used to provide the truth data. For this reason, a low altitude must be used. This restriction will reduce the mission duration for jet aircraft but is unavoidable without extensive instrumentation. During the test flight, the utility of the steering cues should be evaluated as an aid in finding the flyover points in a non-maneuvering environment. Both the INS displays/controls and the accuracy of the cues should be evaluated as an aid in acquiring the points visually in time to overfly the point without excessive maneuvering.

The test is repeated after performing an airborne alignment of the INS. A comparison of the data collected during the two tests then isolates the effects of the airborne alignment. The airborne alignment is discussed in the initialization and alignment test section.

3.3.3.3. Instrumentation

A stop watch and data cards are required for this test, a voice recorder is optional.

3.3.3.4. Data Required

After recording the initialization and alignment data, record the displayed latitude and longitude as a navigation mode is selected. Record the runway and location on the runway, elapsed time, and INS displayed latitude and longitude at takeoff. At each flyover point, record the elapsed time, surveyed point identification, altitude, offset bearing and range if required and INS displayed latitude and longitude. After landing and rolling out, record the runway and location on the runway, elapsed time and INS displayed latitude and longitude. After the taxi back to the hangar, record the surveyed parking location, elapsed time and INS displayed latitude and longitude. Throughout the flight, record as notes on the data cards, any maneuvers requiring over 1.5 g, 30° angle of bank, or 20° of pitch, any airspeed changes of over 50 KIAS (other than takeoff and landing) and any INS system alerts, along with the elapsed time of occurrence. Record qualitative comments concerning the utility of the INS displays/controls and navigation accuracy for navigating to and visually finding the surveyed flyover points in a non-maneuvering environment.

During the airborne alignment test, record the time at which the INS is cycled and the alignment is dumped, then record the time at which the airborne initialization is started. Record qualitative comments concerning the ease and complexity of the data entry. Note if the initialization process interferes significantly with other flight duties. Record the time at which the initialization is completed, and then the time when the flyover alignment is started. Record deviations from straight and level flight and constant airspeed throughout the alignment process as notes. Record the time at which the alignment is complete and then record all the airborne and landing data as outlined above.

3.3.3.5. Procedure

Prior to the test flight, plan a route that provides a flyover point each 5 to 15 minutes of flight time. If possible, plan one flight along a predominately north-south route, and one predominately east-west. Preflight planning of the flyover route is discussed in the navigation theory section. Plan and plot the route using normal low level visual navigation procedures as outlined in reference 59 "Trainee Guide for Visual Navigation". Choose an altitude that can be comfortably flown considering the maneuvering characteristics of the test aircraft, the experience of the pilot, the current weather conditions and the local terrain. Altitudes between 200 and 2,000 feet AGL are standard. VMC is required and care should be taken to choose a route clear of small airfields, areas of dense low level traffic, as well as areas of high bird activity. Generally, standard military VR routes are useful since the route planning has already been performed and scheduling/coordination is fairly simple. References 61 and 62 outline the VR structure and explain procedures for their use. Once a VR route is chosen, only surveyed points leading to and from the home airfield to the start and end point of the VR route need to be selected.

Perform an Initialization and Alignment test as previously outlined. When the alignment is complete, select a navigation mode, start the stopwatch and then record the displayed latitude and longitude. Following the published aircraft and airfield procedures, taxi to the takeoff area and at the time of takeoff, record the elapsed time, and displayed latitude and longitude. Note the location on the runway at the time the position is marked. Surveyed airfield diagrams (usually available at the tower) are later used to obtain the actual surveyed latitude and longitude.

Perform a normal airfield departure, navigating to the initial flyover point. Select an airspeed near the maximum range airspeed at the test altitude and set this airspeed as early as possible. Attempt to maintain this airspeed throughout as much of the flight as possible. Care must be taken to limit maneuvering. Keep g, pitch and bank to a minimum, recording the elapsed time and a complete description of all deviations. Generally, anything over 1.0 to 1.5g, 30° angle of bank, 20° of pitch or 50 KIAS of airspeed change should be noted.

Use visual reference points as well as the test INS and any other available navigation aids to find the first flyover point. The first point should be within 5 to 15 minutes of takeoff and each subsequent point should be at 5 to 15 minute intervals. Record the elapsed time, displayed latitude and longitude and altitude in feet MSL at each flyover point as well as the pilot's estimate of bearing and range to the point at the Closest Point of Approach (CPA) when the point is not directly overflown. Record any system alerts with the elapsed time as notes.

While navigating to the flyover points, evaluate the utility of the INS displays/controls, utility of the INS derived steering cues, as well as the integration of the navigation information within the aircraft as an aid in early visual location of the flyover points in the non-maneuvering environment. After visual location of the flyover point, evaluate the accuracy of the cues until overflight and afterwards the controls, displays and cues as an aid for navigation to the next point. The last flyover should occur 5 to 15 minutes before touchdown.

Following touchdown and rollout, record the elapsed time, runway location, latitude and longitude. Use the description of the runway location to again obtain the surveyed position from airfield charts. Taxi to a surveyed parking area and before shutdown, record the elapsed time and displayed latitude and longitude.

Repeat the test for the case of an airborne alignment. When approaching the first flyover point, cycle the INS, causing the alignment to dump, and start the stop watch. Perform an inflight initialization noting qualitative comments on the parameters listed in the previous section and the elapsed time at the completion of the initialization.

Begin the airborne alignment in conjunction with a flyover update at the first flyover point noting the elapsed time as the alignment begins. During the alignment, fly as straight and level as possible and minimize all speed changes. Note a complete description of any deviations of greater than 0.2 g, 15° angle of bank, 10° of pitch or 15 KIAS of speed change. Continue to fly the originally planned low level route and note the time when the alignment is complete. When complete, resume collection of the flyover data.

3.3.3.6. Data Analysis and Presentation

For points where the aircraft did not fly directly over the flyover point, use the pilot's estimate of bearing and range at the CPA to find the actual latitude and longitude. Convert the bearing to the point to true bearing and then resolve the vector into north-south and east-west components. Next, convert the components into differences in latitude and longitude. In the north-west hemisphere, add the difference in latitude when the point is to the south of the aircraft. Add the difference in longitude when the point is to the west of the aircraft. Use the equations below:

$$T_{bearing}=M_{bearing}-V$$
$$\Delta_{Lat}=\frac{(\Delta nm)}{\left(1\ \frac{nm}{min}\right)} \qquad (24)$$
$$\Delta_{Long}=\frac{(\Delta nm)}{\left[\left(1\ \frac{nm}{min}\right)(\cos(LAT))\right]}$$

Subtract the INS displayed latitude and longitude from the surveyed flyover point latitude and longitude or the offset corrected latitude and longitude, as appropriate. Convert the latitude and longitude difference to nm using equation (21). Plot the data as latitude and longitude error versus elapsed time. Annotate the plots with any significant events noted during the test, such as system alerts or maneuvering above 1.5g, 30° angle of bank, 20° of pitch or airspeed changes of 50 KIAS. Analyze the trend of the plots for the possible causes of the errors as outlined in the navigation theory section. Relate the non-maneuvering accuracy of the INS to the requirement to perform non-maneuvering navigation during ferry missions and while ingressing from the base airfield to enemy lines. Subtract the recorded flyover point altitude above sea level (available from the same data base used to derive the surveyed latitude and longitude) from the recorded MSL aircraft altitude at flyover. 1/2 of this difference is the expected accuracy of the flyover derived truth data for a pilot experienced in the technique. Add an expected error of 25% of the offset range for an offset flyover.

Occasionally the pilot will overfly the wrong surveyed point. If a single point is grossly wrong while the others have plotted a more predictable drift rate, the individual point can be discounted. Occasionally the correct flyover point can be found by interpolating the appropriate navigation error from the curve of the error plot, adding it to the displayed latitude and longitude and then matching the position to the location of similar flyover points in the newly derived area. In this case, the new surveyed point can be used and the data will not be wasted.

If excessive maneuvers are recorded during the flight, check for significant changes in the error curves following the maneuver time. Relate excessive changes in the drift rate to the requirement to perform evasive maneuvers inbound to a target while still requiring accurate navigation information for the return to the home airfield. If system alerts are noted during the flight, check for significant changes in the error rate curve following the time the alert is noted. Thoroughly investigate any INS alerts after the flight. Alerts that imply degraded accuracy and do not result in a change on the error curve or cannot be associated with a system failure should be related to the possibility of unnecessarily aborted sorties (false alarms). Relate the utility of the INS displays/controls, steering cues and integration within the aircraft to the usefulness of the INS as an aid for navigating to waypoints, the target position and later returning to the home airfield.

3.3.3.7. Data Cards

A sample data card is provided as card 40.

CARD NUMBER ___ PRIORITY L/M/H

DYNAMIC NON-MANEUVERING POSITION ACCURACY

[AFTER PERFORMING THE INITIALIZATION AND ALIGNMENT TEST, SELECT A NAVIGATION MODE, START THE STOP WATCH AND RECORD THE LATITUDE AND LONGITUDE. RECORD DATA AT THE TAKEOFF ROLL POINT. AFTER TAKEOFF, SET ___KIAS, CLIMB TO ____ FEET MSL AND ASSUME LOW LEVEL NAVIGATION TO THE FIRST POINT. NAVIGATE TO EACH NUMBERED FLYOVER POINT AND RECORD DATA. RECORD AS NOTES, OFFSET FROM POINT, SYSTEM ALERTS AND MANEUVERS ABOVE 1.5G, 30° ANGLE OF BANK, 20° OF PITCH OR 50 KIAS OF AIRSPEED CHANGE WITH TIME AS REQUIRED. RECORD QUALITATIVE COMMENTS CONCERNING THE UTILITY FOR NON-MANEUVERING FLIGHT OF THE NAVIGATION DISPLAYS, STEERING CUES AND NAVIGATION ACCURACY. RECORD DATA AFTER ROLLOUT AND BEFORE SHUTDOWN.]

SURVEYED ALIGNMENT LOCATION __________ __________

DISPLAYED WHEN SELECTED _________ __________

DESCRIBE TAKEOFF POINT:

ELAPSED TIME AT TAKEOFF _____

DISPLAYED AT TAKEOFF __________ __________

NOTES:

Card 40: Dynamic Non-maneuvering Position Accuracy Data Cards

CARD NUMBER ___ PRIORITY L/M/H

DYNAMIC NON-MANEUVERING POSITION ACCURACY

TIME	POINT #	SURVEYED POSITION	DISPLAYED POSITION	ALTITUDE (FEET MSL)	NOTES:

Card 40: Dynamic Non-maneuvering Position Accuracy Data Cards (Continued)

CARD NUMBER ___ TIME ____ PRIORITY L/M/H

DYNAMIC NON-MANEUVERING POSITION ACCURACY

DESCRIBE LOCATION OF ROLLOUT:

ELAPSED TIME AFTER ROLLOUT ______

DISPLAYED AFTER ROLLOUT __________ __________

SURVEYED SHUTDOWN LOCATION __________ __________

ELAPSED TIME AT SHUTDOWN _____

DISPLAYED AT SHUTDOWN __________ __________

QUALITATIVE COMMENTS CONCERNING UTILITY DURING NON-MANEUVERING FLIGHT OF NAVIGATION DISPLAYS/CONTROLS:

INS STEERING CUES:

NON-MANEUVERING ACCURACY:

Card 40: Dynamic Non-maneuvering Position Accuracy Data Cards (Continued)